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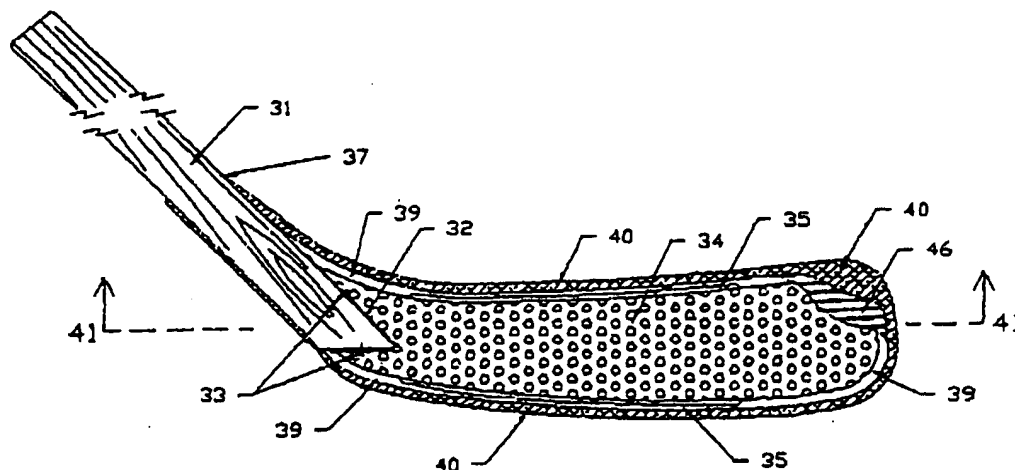
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(54) **BATON DE HOCKEY SUR GLACE INTEGRALEMENT**

**FABRIQUE EN UNE PIECE ET METHODE DE FABRICATION**

(54) **ONE PIECE INTEGRAL ICE HOCKEY STICK AND METHOD**



(57) Bâton de hockey fabriqué en une pièce et composé d'un manche en bois, avec ou sans élément de renfort, et d'une lame avec laquelle il est intégralement fabriqué. La lame est constituée d'un matériau composite léger qui convient à la fabrication de lames pour bâtons de hockey sur glace. La présente invention fait également état de la méthode de fabrication de ce genre de bâton.

(57) The invention consists of a one piece hockey stick with a wooden shaft, with or without composite reinforcement, integrally manufactured with a light weight, composite material hockey stick blade suitable for use in ice hockey, and of a method for producing this type of hockey stick.



**ABSTRACT**

The invention consists of a one piece hockey stick with a wooden shaft, with or without composite reinforcement, integrally manufactured with a light weight, composite material hockey stick blade suitable for use in ice hockey, and of a method for producing this type of hockey stick.

## ONE PIECE INTEGRAL ICE HOCKEY STICK AND METHOD

The present invention relates generally to ice hockey sticks and their method of manufacturing and, more specifically, to one piece sticks manufactured with a wood shaft  
5 molded integrally with a composite sandwich structure blade.

### BACKGROUND OF THE INVENTION

10 Traditionally, hockey sticks for use in ice hockey are made of selected woods with careful attention paid to the quality and orientation of the wood grain for each of the stick components. The shaft and blade are made from four or more individual pieces of wood. The conventional manufacturing process for wooden hockey sticks involves a large number of  
15 individual operations, up to forty per stick. The separate steps include cutting, planing, sanding, laminating, tapering, fitting, bonding and finishing of the various wood pieces that make up the stick, there being typically at least five pieces. If glass fiber or other composite reinforcement is added to the blades the process typically involves more than forty steps. The processing involves the use of only approximately twelve minutes of labor, for high volume manufacture,  
20 but from start to finish, the process takes from five to thirty days with a large percentage of that time required to allow for the drying and curing of adhesive bonding agents.

Developments to improve the stiffness and strength of the stick have included improved quality control of the woods used, lamination of the shafts and the bonding of glass, carbon and  
25 other fibers to the exterior faces of the shaft and the blade. More recently, in an attempt to obtain strong, stiff sticks with reduced weight, hollow shafts of aluminum, composite and hybrids of aluminum and composite have been developed. Separate, replaceable fiber reinforced wooden blades or composite blades are inserted into these shafts to form a stick. These developments have been effective in improving stiffness and strength but have resulted in  
30 increasingly expensive hockey sticks.

Hockey sticks for off-ice or road hockey typically use wear resistant butadiene styrene (ABS) blades attached to wooden shafts, either fiber reinforced or otherwise. These blades are heavy and flexible and are not considered suitable for ice hockey although they are extremely wear resistant and thus suitable for road hockey.

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All composite ice hockey blades can be stiffer, stronger and lighter than conventional blades used in ice hockey, or road hockey blades made of ABS. For example, a composite blade made of a glass and graphite epoxy skinned polyurethane sandwich panel can weigh 160 to 180 grams and have stiffness as high as 75 kN/M while a high performance wood blade with graphite reinforcement weighs about 185 grams with a stiffness of 43 kN/M. The lighter, stiffer composite blade thereby provides the hockey player with a tool that can generate both improved stick handling and shot accuracy.

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Figures 1 and 2 reveal the prior art. Figure 1 shows a one piece wooden stick with a shaft made of wood, laminated wood, or fiber reinforced wood, with an integral blade made of wood or fiber reinforced wood. It comprises a shaft 11 which is gripped by the hands of the player and a blade 13 integrally attached to the shaft and used to control and strike the hockey puck. The bottom portion of the connection between the blade and the shaft is called the "heel" as denoted by 12 and the opposite end of the blade is called the "toe" which is denoted by 14.

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Figure 2 shows a hockey stick comprising a hollow shaft 21, typically of composite, aluminum, or a combination of the two materials. A separate blade 22 made of wood, fiber reinforced wood, plastic or fiber reinforced composite which is inserted into the end of the hollow shaft 21 and held by adhesive, friction fit, or some form of mechanical connection. The heel 12 and toe 14 are as defined in Figure 1. The extension of the blade which is inserted into one hollow end of the shaft is called the "tenon" 23. The vertical portion of the blade extending downward from the tenon 23 to the heel 12 is known as the hosel 24 (sometimes spelled hozzel or hazzle). A wooden or plastic plug 25 is sometimes inserted in the upper end of the shaft 21 opposing the blade end.

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The prior art as expressed in patents, patent applications and commercial literature reveals some inconsistencies in the terminology used to describe hockey stick components. In particular, both the shaft and the end plug are sometimes referred to as the "handle" of the stick. The tenon is sometimes referred to as the shank. This application will conform to the definitions of Figures 1 and 2.

Canadian Patent Application 2,037,273 discloses a method for manufacturing a hockey stick from preforms for both the composite blade and a composite shaft and molding the two preforms together in a final step. This is a method for producing an all composite stick using a 12 step wrapping and molding process. The use of all composite construction and a 12 step process results in an expensive all composite stick.

Canadian Patent Application 2,057,663 discloses a foam core hockey stick with aramid and carbon face sheets over the core. This is also an entirely composite stick.

Canadian Patent Application 2,062,635 describes the manufacture of an all composite hockey stick from a separately manufactured composite shaft and blade.

Canadian Patent Application 2,099,853 discloses a method for manufacturing a composite blade by injection molding. The blade is designed to be inserted into a hollow shaft, preferably a hollow metal shaft.

Canadian Patent Application 2,108,069 discloses a method for manufacturing a composite hockey stick shaft with a metallic insert embedded at one end to accept a separate blade and a standard wooden end plug at the opposite end of the shaft. The patent refers to this end plug as a "wooden handle" but it is clear from the description and figures that this is an end plug in a hollow composite shaft. The composite shaft disclosed by this application is not integrally formed with a blade.

Canadian Patent Application 2,117,987 discloses a method to injection mold sports implements such as cricket bats or golf club heads with inserts into the casting. The molded material is not reinforced with continuous fibers as required to provide stiffness to hockey stick components.

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Canadian Patent 1,063,747 discloses a composite reinforced blade structure for a hockey stick. The composite blade consists of a foam core surrounded by a glass fiber reinforced plastic skin. The blade is formed with a "handle receiving cavity" molded into it. A metal insert is used to form this cavity. The blade is formed in one piece, and the shaft is secured to the cavity by adhesive in a subsequent separate operation. It is not clearly stated that the metal insert is removed to form the cavity but that is implied. A shaft is then inserted into this cavity and secured by an adhesive. This patent refers only to glass fiber reinforcement. The adhesive joint bonding of the shaft to the blade results in a much weaker joint than the one of the present invention.

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Canadian Patent 1,233,738 discloses a method for manufacturing a hockey stick with the outer layers of both the blade and the core consisting of fiber composite material. The entire stick is molded in one piece. The blade can contain a wooden core, or a plastic foam core. The shaft is formed over a mandrel, which can be removed, leaving a hollow composite shaft, or over a foam core, which can be left in place. The result is a hollow or foam cored composite shaft formed to a composite blade with a wood or foam core.

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United States Patent 4,124,208 discloses and one piece stick with a foam filled honeycomb core and metal skins on both blade and shaft.

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United States Patent 4,537,398 discloses a fiber reinforced wooden blade molded integrally with a fiber reinforced wooden shaft. This results in a typical fiber reinforced wooden stick. The core of the blade is made of wood. The manufacturing process involves all of the various steps required to manufacture a wooden stick with added steps to apply the composite reinforcement.

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United States Patent 5,050,878 discloses a polyvinyl chloride (PVC) foam core stick where the core is wrapped in glass and carbon composites.

5 United States Patent 5,160,135 reveals another example of a wooden stick with composite reinforcement applied to an all wooden stick. The core of the blade is also made of wood.

10 United States Patent 5,217,221 discloses a one piece composite stick with a wooden veneer molded to cover the entire outer surface of the stick. Both the shaft and blade underneath the wood veneer are molded of composite material.

### SUMMARY OF THE INVENTION

15 The present invention overcomes the above shortcomings.

20 Accordingly, an object of the present invention is to provide a method of manufacturing a one piece integral hockey stick and thereby a resulting one piece hockey stick with an extremely strong joint between a wooden shaft and a composite blade which is manufactured by a fast, low cost method and which is lighter, stiffer and more impact resistant than conventional wood, laminated wood or fiber reinforced wood shaft. There is no innovation claimed with respect to the shaft except as regards the method by which it is manufactured into the integral stick with a composite blade. The shaft is of conventional hockey stick shaft dimensions and is of a generally rectangular cross section. The edges can be radiused or beveled. The faces of the shaft, can be slightly concave or convex, or combinations of concave, convex. Reinforcing sheets or continuous fiber reinforced plastic, can be applied to the faces of the shaft in the conventional manner or they can be attached by a wet roving application process followed by molding with applied heat and pressure. There is no innovation claimed as to the use of fiber reinforced plastic on the faces of the shaft.

In accordance with another object of the invention there is provided a one piece integral ice hockey stick which is the combination of a composite blade with a conventional wood or a laminated glass-wood shaft in a one piece construction. It is lighter than a regular wood hockey stick and it has a stiffer blade to allow for improved stick handling, more accurate shooting and a longer life, as the wood blade generally breaks before the wood shaft whereas the composite blade is stronger than the typical wood blade. The prior art reveals that 69% of all hockey stick failures occur in the blade (25%) or at the junction of the blade and the shaft (44%). Only 31% of failures occur in the shaft itself. Thus a process that joins a high performance blade to a conventional wooden shaft with a high strength bond could be projected to extend the average life of a hockey stick by over 200% while offering improved playing performance from the stiffer, lighter composite blade as compared to the standard wood blade. A major benefit of this invention is that the wood shaft is integrally joined to the composite blade under elevated temperature and pressure, hence the resin penetrates the wood to a depth of several millimeters making a very strong bond in the area where 44% of wooden stick failures occur. As well, 360° composite reinforcement surrounds all four faces further integrally strengthening this key hosel area.

In accordance with still another object of the invention there is provided a one piece integral ice hockey stick which is suitable for use in ice hockey which provides strength, stiffness and feel approaching that of expensive, all composite sticks at a cost competitive with low cost wooden sticks of far inferior strength and puck shooting accuracy.

In accordance with still another object of the invention there is provided a method to reduce the time and number of manufacturing steps required to produce a hockey stick. The stick is manufactured using less than one quarter of the typical forty steps required to manufacture a good quality wood or fiber reinforced wood stick. Thus a one piece hockey stick with an extremely strong joint between a wooden shaft and a composite blade is claimed which is manufactured by a fast, low cost method and which is lighter, stiffer and more impact resistant than conventional wooden sticks and less expensive than all composite sticks.

In accordance with yet another object of the present invention there is provided a method of manufacturing an integral hockey stick comprising the following steps: a) shaping the end of a wooden shaft; b) making a foam blade preform; c) attaching said preform to the shaft; d) molding the blade to the shaft; and e) trimming the stick: whereby a wooden shaft and a composite blade are integrally bonded in one operation to form a one piece hockey stick.

In accordance with still yet another object of the present invention there is provided a one piece ice hockey stick comprised of a wooden shaft and a composite blade where the composite blade is manufactured and integrally bonded to the shaft in one operation resulting in the formation of a strong bond between the blade and the shaft due to the penetration of resin into the surface layers of the shaft under elevated temperature and pressure, as well as having 360° composite reinforcement surrounding all four faces further integrally strengthening a hosel area.

Further objects and advantages of the present invention will be apparent from the following description, reference being made to the accompanying drawings wherein preferred embodiments of the invention are clearly shown.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be further understood from the following description with reference to the drawings in which:

Fig. 1 is a side view of a conventional one piece stick used to illustrate the component terminology;

Fig. 2 is a side view of a typical stick assembled from a separate shaft, blade and end plug, used to illustrate the component terminology;

Fig. 3 is a longitudinal section through one preferred embodiment of an integral one piece stick made according to the present invention; and

Fig. 4 is a transverse longitudinal cross section of the blade and shaft of Figure 3 taken along line 41-41 in Figure 3 and a blow-up of part of the cross-sectioned blade.

### DETAILED DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the invention is the integral forming and bonding of a wood or reinforced wood shaft of any construction to a composite sandwich structure blade of any construction using any suitable core material and any combination of fiber resin reinforcements in the skins that will provide the required strength, stiffness and weight of the blade while ensuring a very strong bond to the shaft insert around which the blade preform was constructed.

Different hockey players require different weights and stiffnesses of stick and blade. Thus the choice of fiber architecture, that is fiber type, locations and orientations, will depend on the player's requirements. The process is suitable for use with a very wide range of cores and fiber architectures. One preferred embodiment to illustrate the invention is generally indicated in Figs. 3 and 4.

The shaft of the stick 31 is tapered and sized to fit the geometry of the preform fiber architecture such that the desired finished blade thickness is obtained. In this embodiment one layer of spun glass rovings 33 is placed on the frontal face of the shaft and the bottom end of the shaft where it will butt against the core of the preform. A fiber reinforced wooden shaft could also be used, wherein the fibers are continuous and are oriented substantially parallel to the length of the shaft. The reinforcing fibers are preformed into pultruded or laminated sheets or prepregs with resin and are adhesively bonded to the shaft as laminates. Wood laminates are

also bonded to the shaft to cover the fiber reinforcements. A preform core about 9 mm thick in the shape of a hockey stick blade is attached to the shaft by several metal staples 32 on each side. The preform core 34 in this embodiment is made from, but not restricted to 6 lb per square foot density thermoplastic polyurethane foam. A braided glass sock, or tube 35 open at either end, of approximately 18 cm length, is placed over the preform centered on the puck striking area in the middle of the face of the stick. It is constructed of e-glass oriented at  $\pm 45^\circ$  to the longitudinal axis of the sock 35 and weighs 57 grams per meter and is 4.4 cm in diameter. Stitched unidirectional graphite fiber 46 made of T300, 12 K graphite tow with a yield of 340 grams per meter is placed over both faces of the blade and curved to run along the shaft to point 37 where the shaft emerges from the blade preform. A layer of  $\pm 45^\circ$  T300, 12 K graphite fabric 48 with a yield of 400 grams per meter is placed over each face of the shaft where it meets the preform to reinforce and strengthen the joint. A spun glass roving 39 of 225 yield is wrapped around the bottom edge, toe and top edge of the blade and held in place by loops of polyester thread. A second braided glass sock 40, of identical construction to sock or tube 35, open at either end, of approximately 30 cm length, is placed over the preform and extends from the toe of the blade to the point 7.

This preform is saturated with a carefully metered amount of rubber modified toughened epoxy resin sufficient to fully wet the preform and yield a fiber loading of over 65% by volume when the skins have been consolidated and cured.

The fiber preform and the shaft up to point 37 are placed into the bottom cavity of a mold shaped to yield the final morphology of the designed blade. The top half of the mold is closed and the shaft extends out of the mold and is supported by a fixture to ensure that the required geometrical orientation of the blade and shaft is maintained. Standard compression molding insert sealing techniques are used where the shaft extends from the mold to prevent resin outflow. The preform and shaft joint assemble are cured at  $150^\circ\text{C}$  and a molding pressure of between 350 and 800 psi, preferably 600 psi for 5 minutes. The part is removed and flash from the molding process is trimmed and the required graphics applied.

Further describing the process, the lower end of the shaft is reduced in section to a profile suitable for integration within the composite blade component. This profile can consist of a taper or of a taper terminating in a short reduced width section with generally rectangular shape. A glass roving can be attached to some or all of the faces of the shaft, and the bottom of the shaft, including the lower end face of the shaft. Grooves can be cut, at angles varying from 0° to 90° to the longitudinal axis of the shaft, into the surface of the shaft where it will mate with the blade to improve the interlock of the blade and the shaft. These grooves can be lightly filled with glass rovings as well. The glass rovings in each case can be tacked in place by mechanical fasteners, such as staples, by a loop or loops of any suitable thread material or by small spots of hot melt thermoplastic adhesive, methacrylate type adhesive or any other suitable adhesive. The fastening method, whether adhesive or mechanical, is only used to locate the rovings prior to assembly and molding. A core is molded into the outline of a hockey stick blade and reduced in size to allow for the addition of composite outer skins to form the finished blade. This core is attached to the lower end of the shaft by mechanical fasteners such as staples. The core can be, but is not restricted to any suitable thermoset or thermoplastic foam, with or without fiber or particulate reinforcements; any suitable syntactic foam or any type of honeycomb material where the honeycomb walls are oriented across the narrow dimension of the core. The fasteners are only used to locate the core of the blade during the subsequent manufacturing steps and do not constitute the mechanism by which the shaft will be bonded to the finished blade. The core is covered with layers of fibrous material such as, but not restricted to, glass, graphite and aramid. These fibers can be in the form of mat, cloth or rovings. The reinforcement can be applied in the form of expandable braided or woven socks, or of woven or stitched fabrics or of rovings. Fabric can be placed in several layers with fibers of the appropriate type for the loading found in use placed in suitable points of the laminate. For example, the lateral faces central part of the blade can be reinforced with two or more layers of glass or other fiber braid to improve the fracture resistance of this area which is used to strike the puck. One or more layers of unidirectional fibers or fabric, in particular  $\pm 45^\circ$  fabric, can be used to reinforce the lateral sides at the point at which the shaft touches the core. Fibers, usually in the form of mat or braided socks are wrapped around the entire blade assembly. The amount, type and orientation of fibers are selected to provide the desired weight, stiffness and

strength of the blade and shaft assembly. One or more glass ropes or rovings can be wrapped around the perimeter of the blade and held in place by a mechanical fastener, a dab of suitable adhesive or loops of a suitable thread. When formed into a composite in the final part, this rope or roving layer will form a wear resistant strip on the bottom of the blade and a curved cosmetic finish for the perimeter of the blade.

The blade preform and the lower end of the shaft which is inserted in that preform are wetted with a suitable resin, such as, but not restricted to, epoxy or a thermoplastic resin such as nylon. This preform and the lower end of the shaft are then subjected to carefully controlled heat and pressure to mold the blade into place integrally around the shaft thereby bonding it strongly to the shaft. Fixtures locate the blade preform and the shaft to ensure the desired orientation of the two components as they are formed into the integral stick. The heat and pressure can be applied by matched die compression molding, resin transfer molding, resin injection molding, vacuum bag processing or other processes. The blade preform can be laterally curved to any desired curvature typically used by hockey players. If the blade preform is assembled from thermoplastic core and resin materials, it can be molded into different curvatures by the application of heat and force or pressure subsequent to the initial manufacturing process for the integral stick.

It follows that this method produces a stick starting from a "bought-in shaft" in which a total of 6 operations take place. First, the shaping of the end of the shaft takes place, then followed by the attachment of the rovings to the shaft, and the making of the foam blade preform. Then the preform is attached to the shaft, followed by the molding and finally the trimming of the resulting stick.

The resulting stick has a very strong bond of the shaft to the blade. It will resist breakage at the shaft to blade joint, which is in this invention a three dimensional unitary joint, longer than a wood stick under similar usage conditions. It has a higher shaft to blade strength because the blade is integrally bonded to the shaft under conditions of elevated temperature and

pressure, forming a strong bond where resin penetrates into the wood surface under pressure. As well, 360° composite reinforcement surrounds all four faces further integrally strengthening this key hosel area. Micrographic examination reveals that the resin penetrates as far as 5 mm into the wood, integrally joining the wood shaft to the blade.

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The stick is manufactured in less than ten minutes, with no requirement for storage while adhesives dry. It can therefore be produced at a cost which is less than a conventional one piece all wood stick.

10 This resulting stick has a shaft stiffness identical to a wood stick with the same shaft, but the blade is 20% stiffer than the comparable wood blade and the stick weighs approximately 25 grams, or 5% less than a typical wood stick.

15 Other preferred embodiments may include the use of any other foam or syntactic foam in the core including fiber reinforced foams where the fibers include, in proportions varying from 0 to 100%, but are not restricted to glass, graphite, aramid, boron, alumina, thermoplastics, or the use of any type of honeycomb in the core, or the use of any fiber architecture, e.g. all graphite, more graphite, less glass, etc., or the use of thermoplastic resins for the skin of the blade that will allow post forming of the blade in the shop to reduce stocking requirements for  
20 a range of blade stiffnesses and curvatures, or the use of notches in the end of the shaft with embedded glass or other fiber rovings to enhance the bond of the blade to the shaft by forming a mechanical interlock with composite tongues locking into wood grooves.

25 The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method of manufacturing an integral hockey stick comprising the following steps:
  - a) shaping the end of a wooden shaft;
  - b) making a foam blade preform;
  - c) attaching said preform to the shaft;
  - d) molding the blade to the shaft; and
  - e) trimming the stick;whereby a wooden shaft and a composite blade are integrally bonded in one operation to form a one piece hockey stick.
2. The method of claim 1 wherein a fiber reinforced wooden shaft is used.
3. The method of claim 1 wherein the blade or shaft is reinforced with any combination of glass, graphite, aramid, boron or alumina fibers wherein the percentage of each fiber species used can vary from 0 % to 100% in each component.
4. The method of claim 2 wherein the fibers are continuous and are oriented substantially parallel to the length of the shaft.
5. The method of claim 4 wherein the fibers are preformed into pultruded or laminated sheets or prepregs with resin and are adhesively bonded to the shaft as laminates.
6. The method of claim 5 wherein wood laminates are bonded to the shaft to cover the fiber reinforcements.
7. The method of claim 4 wherein the fibers are bonded directly to the shaft with a wet resin process.

8. The method of claim 1 wherein glass fibers are attached to the surface of the shaft where it will be overlapped with the preform.
9. The method of claim 8 wherein the glass fibers are set in grooves cut into the surface of the shaft.
10. The method of claim 9 wherein the grooves are cut at any angle to the longitudinal axis of the shaft from 0° to 90°.
11. The method of claim 1 wherein the composite blade is formed with a thermoplastic foam core.
12. The method of claim 11 wherein the foam core is a thermoplastic polyurethane.
13. The method of claim 12 wherein the foam core is toughened.
14. The method of claim 12 wherein the foam core is reinforced with fibers.
15. The method of claim 14 wherein the fibers are any combination of glass, graphite, aramid, boron, alumina or thermoplastic fibers wherein the percentage of each fiber species used can vary from 0 % to 100%.
16. The method of claim 1 wherein the composite blade is formed with a syntactic foam core.
17. The method of claim 1 wherein a honeycomb core is used.
18. The method of claim 1 wherein hollow glass fibers are used to reinforce the blade or the shaft.
19. The method of claim 3 wherein the fibers reinforcing the blade are installed onto the foam core as braided or woven socks.

20. The method of claim 1 wherein the resin used to manufacture the blade is a thermoset.
21. The method of claim 20 wherein the resin contains epoxy.
22. The method of claim 21 wherein the epoxy is rubber modified to toughen it.
23. The method of claim 1 wherein the resin used to manufacture the blade is a thermoplastic.
24. The method of claim 1 wherein the blade is formed by matched die compression molding.
25. The method of claim 1 wherein the blade is formed by resin transfer molding.
26. The method of claim 1 wherein the blade is formed by vacuum bag processing.
27. The method of claim 1 wherein the core of the blade contains ABS with foam inserts.
28. The method of claim 1 wherein the core of the blade contains ABS with honeycomb inserts.
29. The method of claim 1 wherein the faces of the shaft are slightly concave or convex, or combinations of concave, convex and straight on a single shaft.
30. A one piece ice hockey stick comprised of a wooden shaft and a composite blade where the composite blade is manufactured and integrally bonded to the shaft in one operation resulting in the formation of a strong bond between the blade and the shaft due to the penetration of resin into the surface layers of the shaft under elevated temperature and pressure, as well as having 360° composite reinforcement surrounding all four faces further integrally strengthening a hosel area.

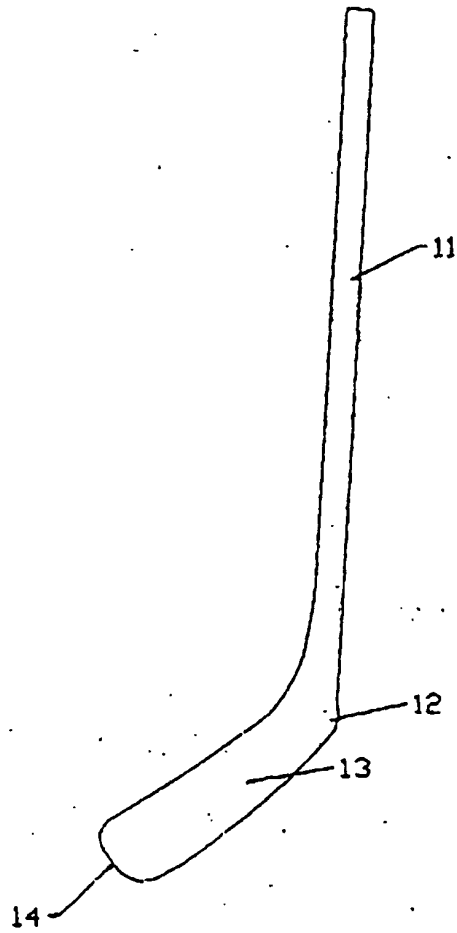


FIG.1

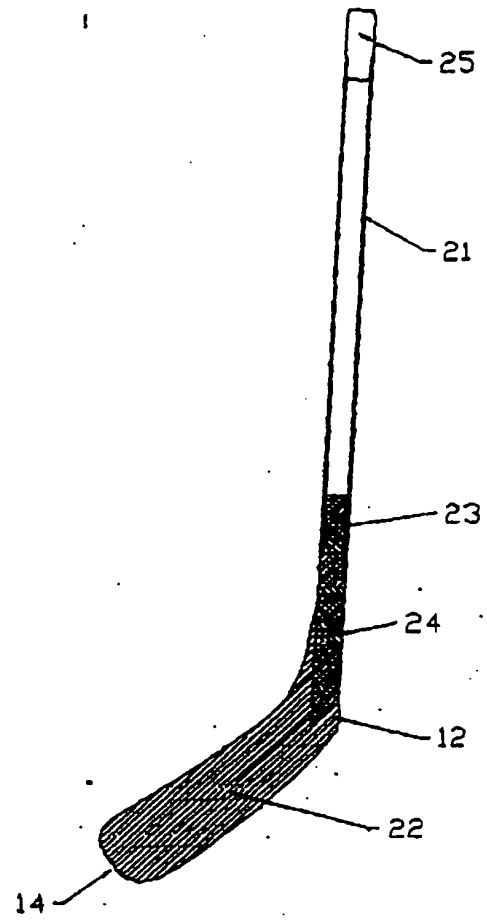


FIG.2

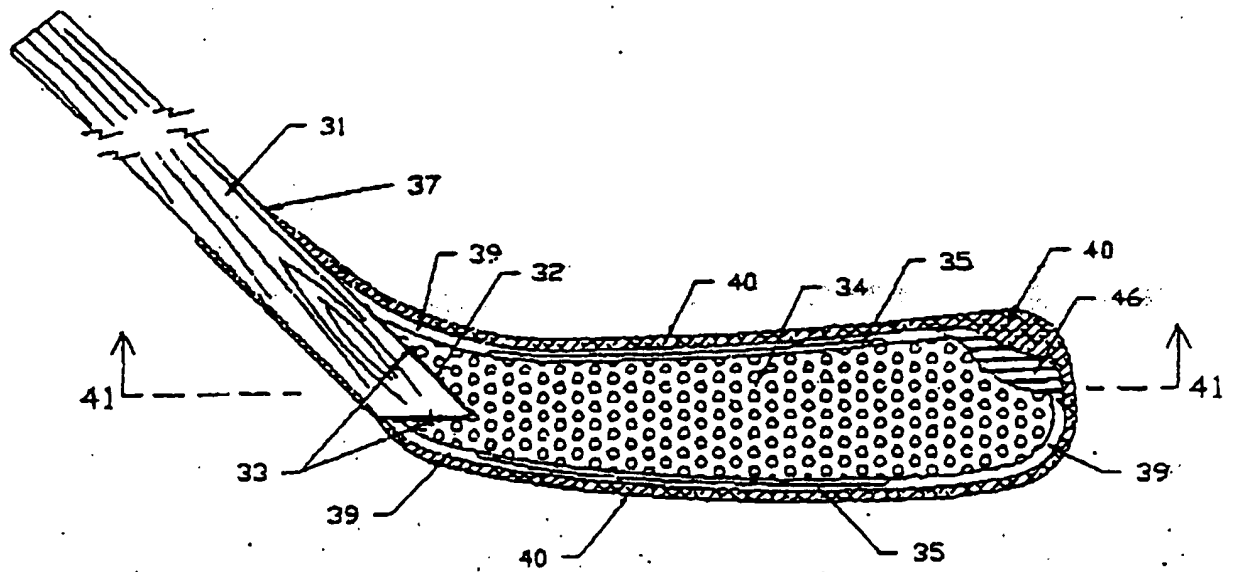


FIG. 3

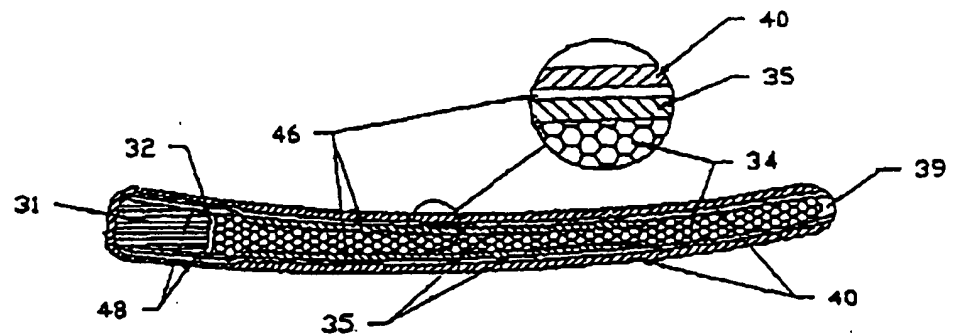


FIG. 4

